Factors Influencing Occurrence, Scale, Mobility, Runout, and Morphology of Mass Movements on the Continental Slope

Homa J. Lee
U.S. Geological Survey, M/S999, 345 Middlefield Road
Menlo Park, CA 94025
650-329-5485 (phone) 650-329-5411 (fax) homa@octopus.wr.usgs.gov

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LONG-TERM GOAL

Achieve an improved understanding of the relationships between sedimentation, environment, and the morphology of continental slopes. This goal will be accomplished primarily through investigations within the northern California (Eel River) study area. An underlying assumption of our work is that the occurrence and morphology of mass movement features on the continental slope depend upon a combination of characteristics, each of which varies over the region in a consistent manner. We will apply data from other ongoing studies to augment and expand the usefulness of our information obtained in the northern California study area. Our work is closely coordinated with the geotechnical group at Laval University (Dr. Jacques Locat), but for administrative reasons, our work is funded separately by ONR.

OBJECTIVES

Identify and measure factors, such as steepness, seismicity, sediment strength, and pore pressure, that can be mapped regionally and that determine where and how slope failures occur. Derive a basis for producing regional maps that indicate relative landslide susceptibility. Evaluate the circumstances under which mass movements determine the steepness of the continental slope and contrast these circumstances with those in which the steepness is controlled by other factors.

APPROACH

Our research focuses on the factors that lead to variations in the sedimentological and environmental conditions determining slope failure. We develop improved correlations between engineering classifications and strength factors. We measure excess pore water pressures in situ. We simulate sediment accumulation in specially designed cells. Geotechnical properties are related to sediment density state, obtained from detailed logs of downcore variability of sediment density and sound velocity. Using available bathymetry, we construct slope maps. Seismic shaking variations are evaluated probabilistically by seismologists. Driving stresses are balanced against strength variations in a geographic Information System (GIS) to obtain a regional estimate of relative slope stability.
Key individuals: Homa Lee, Diane Minasian, Peter Dartnell, and Florence Wong: physical property logs of sediment cores and relations between geotechnical and classification properties, algorithms relating sediment properties, environmental factors, and slope stability within the framework of a GIS.
Collaborators : Jacques Locat, Jean-Marie Konrad, Harold Christian, Eric Boulanger, Priscilla Desgagnes, Francis Martin and Frederic Laurent (Laval University) detailed geotechnical property measurement, SEM studies, and assessment of compressibility, rheology, and shear strength

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development; Harold Christian (Geological Survey of Canada): measurement of excess pore water pressures in situ.

WORK COMPLETED

We conducted an oceanographic cruise to the Eel Margin on the R/V Wecoma (July 17-24, 1998) to satisfy the goals of this project and to provide sediment samples and data for other investigators. In collaboration with J. Locat and H. Christian, we conducted in situ piezometer tests to determine whether excess pore water pressures exist in Eel Margin sediment and the potential impact these pressures might have on slope stability. We determined that excess pore pressures were not significant in the upper few meters of the sediment column at 5 stations where measurements were made. We obtained a total of 29 box core samples and 15 high quality Lehigh gravity core samples on the Eel slope and fan. Approximately one half of these samples will be used by J. Locat to measure strength and compressibility properties, and the results will be integrated into our overall study of geotechnical properties and slope stability. Nine cores were taken in unique acoustic facies to groundtruth high resolution subbottom profiles and multibeam bathymetry backscatter. Other cores were taken to support C. Alexander. All cores were logged at 1-cm resolution for density, sound velocity, and magnetic susceptibility using our multi-sensor whole core logger. Cores from 1997 were tested for shear strength and Atterberg limits. We entered these data into a GIS to evaluate regional variations in sediment properties and environmental loads. Algorithms convert these data into estimates of slope stability.

To expand the applicability of our results, we are conducting a comparative study of the Los Angeles Margin using data obtained by Lee as part of a sediment pollutant transport study. We have prepared maps of the Los Angeles margin that show the distribution of relative slope stability. These studies are valuable because the Los Angeles margin shows a much broader distribution of slope failure features and the set of available data is as extensive as that from the Eel Margin.

RESULTS

Classic slope failure features on the Eel Margin are rare even though our methodology shows a high vulnerability to slope failure during seismic loading, indicating either that mass wasting on the Eel Margin takes unexpected forms or that mass wasting is less significant than would be expected. Shallow-seated failures are more common on the Los Angeles Margin. Our methodology shows an even higher vulnerability to slope failure in Los Angeles Margin areas experiencing numerous shallow-seated failures. Our methodology shows promise in terms of delineating the environmental conditions that are conducive to shallow-seated submarine slope failure.

IMPACT/APPLICATION

Relationships developed in this project show the importance of sediment liquidity index and seabed density profiles in representing the behavior of marine sediment. These values can be used to predict regional slope stability and the rheological behavior of debris flows. This project shows the value of GIS techniques in combining the impact of a variety of marine sediment and environmental factors to yield information about a predicted outcome, in this case, susceptibility to slope failure.

TRANSITIONS

Geoacoustic properties are being used by mappers and acousticians to identify lithologies acoustically. Rheological properties are being used by modelers to represent debris flows. Landslide generation models are being used by landscape evolution modelers.

RELATED PROJECTS

Lee has developed a USGS project to investigate sediment and pollutant transport on the Los Angeles margin using many of the same techniques produced by STRATAFORM.

PUBLICATIONS

Boulanger, E., Konrad, J.-M., Locat, J., and Lee, H.J., 1998. Cyclic behaviour of Eel River sediments: a possible explanation for the paucity of submarine landslide features, Eos (abstract in press).

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